

Fire Station Rainwater and Greywater Harvesting for Beneficial Reuse

Technical Brief

What is Water Harvesting?

Water harvesting is the capture and storage of water for beneficial reuse. It can be accomplished anywhere a water supply is available for collection-and a water source is desired or required. To understand the process fully, it is important to understand water harvesting terms.

Rainwater harvesting is the capture and storage of rainwater and is considered the cleanest form of harvested water.

Greywater harvesting is the capture and storage of water that has already been used for non-sewage purposes-from baths and showers to washing machines, sinks, and vehicle washing run-off.

Reclaimed water is greywater that has been treated for water quality. Reuse of reclaimed water triggers significantly more code requirements and design regulations than reuse of rainwater.

Potable water is clean water-satisfactory for drinking, culinary, and domestic purposes, and meets the drinking water standards established by the Washington State Department of Health.

Drillwater harvesting is the capture and storage of water from a potable source that was used for fire department drills. While drill water is not considered rainwater it can be treated in a similar manner if it is collected from surfaces with similar pollutant concerns.



The Beckoning Hand Rainwater Cistern on Vine Street, Seattle, WA. Image courtesy of Mayfly Engineering and Design.



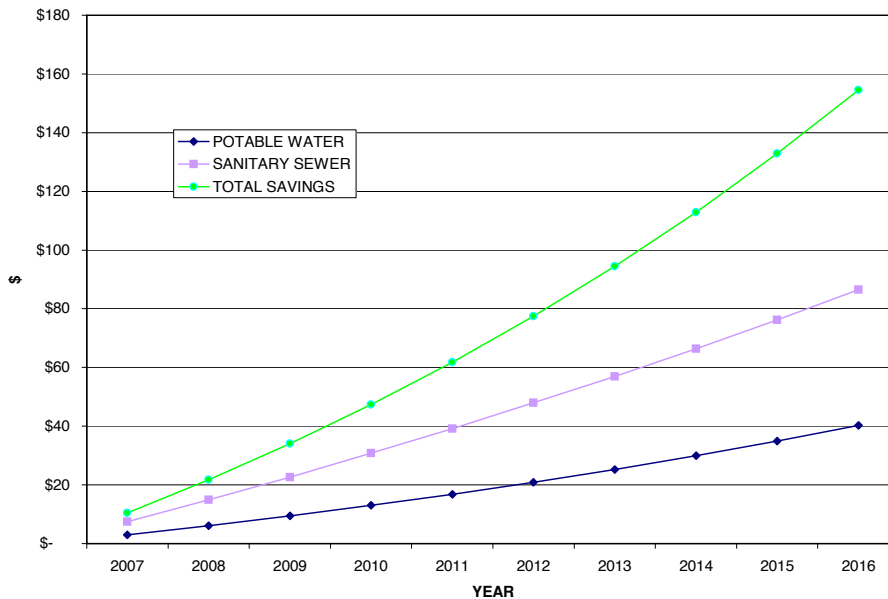
What are the goals and benefits of water harvesting?

Water harvesting provides a host of design benefits such as reducing the demand on city potable water systems, city sewer infrastructure, and stormwater detention systems. Additionally, rainwater collection

in combined sewer neighborhoods can reduce the amount of pollutants released into lakes, streams, and other water bodies during combined sewer overflows.

Perhaps the most obvious benefit to water harvesting, however, is reduced utility rates for building owners. While today's rates are still considered low, water rates in the City of Seattle have been rising at an average rate of 10.5% a year over the last 16 years. City of Seattle Sanitary Sewer rates have been rising an average of 7.5% a year over the last 15 years. The City of Seattle bases sanitary sewer rates on water usage, unless an irrigation deduction meter is installed. The graph to the left shows that for every 100 cubic foot (one cf is equal to 748 gallons) of potable water saved per year, the ten-year payback will be over \$125. Extend this period to 25 years—a typical lifecycle analysis period—and for every 100 cf of potable water saved, per year, accumulated savings is shown to be over \$500.

ACCUMULATED UTILITY RATE SAVINGS PER CCF OF WATER SAVINGS
1 CCF = 100 CF = 748 GALLONS



Accumulated utility rate saving figure courtesy of Mayfly Engineering and Design, January 2007.

LEED Benefits for Water Harvesting!

The City of Seattle calls for all new City-funded projects and renovations with over 5,000 square feet of occupied space to achieve a LEED Silver rating. Water harvesting can contribute towards the following LEED credits:

- Sustainable Sites Credit 6.1 Stormwater Design: Quantity Control
- Water Efficiency Credit 1.1 Water Efficient Landscaping: Reduce by 50%
- Water Efficiency Credit 1.2 Water Efficient Landscaping: No Potable Water Use or No Irrigation
- Water Efficiency Credit 2.0 Innovative Wastewater Technologies
- Water Efficiency Credit 3.1 Water Use Reduction: 20% Reduction
- Water Efficiency Credit 3.1 Water Use Reduction: 30% Reduction
- Innovation in Design : Potable Reduction for Process Water
- Innovation in Design: Education Credit

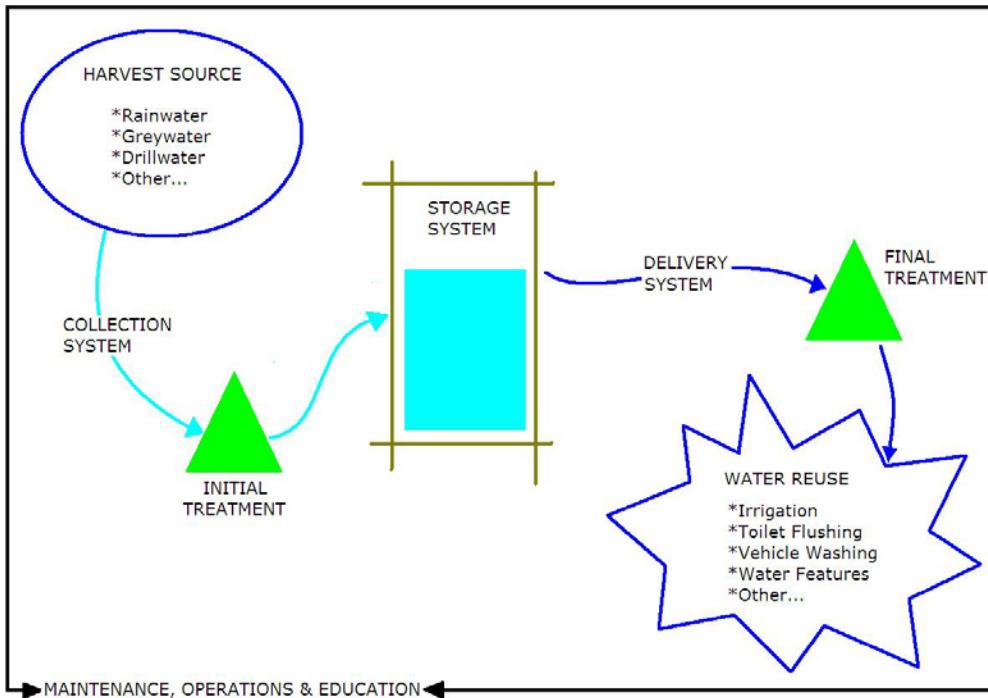
For more information on LEED credit specifics visit the USGBC LEED web site at <https://www.usgbc.org>

Incentives

Seattle Public Utilities provides a 10% reduction in annual commercial stormwater fees for projects that are shown to meet stormwater best management practice (BMP) and reduce rainwater runoff from their site.

Both rainwater and greywater harvest systems typically consist of the following components:

Water Harvest System Design



Water Harvest System Schematic, Image courtesy of Mayfly Engineering.

Harvest System Components

- **Harvest sources:** Depending on system types, this can consist of a variety of sources including rooftops, drill aprons, or drainage pipes from building fixtures. Sources can also include rooftops and collection areas from neighboring buildings.
- **Collection systems:** Collection systems include piping, inlets, or other conveyance needed to route harvested water from harvest sources to the storage system. This can range from conventional roof drains to double interior mechanical piping systems.
- **Initial Water Quality Treatment:** Pre-storage treatment is used to divert debris and/or first flows which typically contain the greatest concentration of rooftop pollutants prior to entering the storage system, and to keep leaves and other larger debris from entering and clogging the system.
- **Storage system:** Storage systems can be constructed from a variety of materials and placed in various locations. These systems can include tanks, pipes, and enclosed portions of buildings-above or below ground level. Materials include underground concrete and fiberglass, partial and above ground plastic, and enclosed basement structures.

- **Delivery System:** Delivery may be accomplished by a gravity system or include the pumps and pipes needed to move water from the storage system to the end use.
- **Final Water Quality Treatment:** This treatment is often done as part of the Delivery System. The extent of water quality treatment is dependent on both the quality of the water entering the storage system and the desired reuse. Systems range from simple cartridge filters to UV light and chlorination.
- **Operations and Maintenance Manual:** This document should include all operations and maintenance information needed to ensure proper function of the harvest system, and ensure the system meets all applicable building codes.
- **Education Program:** Written documentation of this program can be included in the Operations and Maintenance Manual. All users and system operators need to understand how to operate and maintain the system in order to ensure proper function. This can be done with training and/or signage. User behavior patterns should be encouraged that minimize the wasting of water.
- **Public Information Materials:** Additional information to inform the public of the system benefits and operation can be included in a project through signage. An education program can also be developed to allow non-users (the public) to learn about the benefits and operation of a water harvest system.

System Component Design Considerations

The design of each water harvest system is unique to each project. (See Regulations, Guidelines and Design Resources for in-depth information to base specific system design decisions on.) However, there are several basic considerations to take into account in the design process.

- **Harvest sources:** Specify all roofing and piping materials to meet user and code requirement for water quality, color and porosity.
- **Collection systems:** Specify systems that minimize maintenance efforts.
- **Initial Water Quality Treatment:** Select appropriate systems for your site location and end use. (The Regulations, Guidelines and Design Resources section includes references to information sources that will help you identify system specific systems.) Leaf screens and self cleaning bug screens are a typical choice for rainwater harvesting in the Pacific Northwest. The first rainfall that runs off the rooftop typically contains the greatest concentration of pollutants. A first flow diverter directs the first flow away from the storage system. First flow diverters are typically used in waterfront locations (seagull havens) or areas with overhanging debris.
- **Storage system:** All storage systems should have a designated overflow route for collected water that exceeds the systems available storage capacity. The overflow must meet stormwater code and might consist of a conventional connection to a detention system or sewer main or a site feature such as a rain garden or infiltration system. Provide a potable water supply for maintenance and/or for make-up water. Get creative with cistern locations (i.e. is there a corner in the basement that could be enclosed with two walls and a liner?).
- **Delivery System:** Label all water access points such as hose bibs and toilets as non-potable unless treated to potable water standards. If sufficient head is available to obtain needed system pressure, the system may operate without pumps as a gravity system. This portion of the system must also

include cross connection and back-flow prevention elements to protect back-up potable water systems per code. Consider designing a potable water back-up that can operate without electricity for emergency conditions.

- **Final Water Quality Treatment:** Ensure that water quality treatment meets any and all code requirements for your system specifics.
- **Operations and Maintenance Manual:** The manual should include information on replacing and/or cleaning filters, removing sediment and other pollutants from storage system, backflow prevention inspections, valve schedules and operation, backup and cross connection, seasonal start up and shut down, freeze protection.

Other water harvest system component considerations include:

Structural Support

Consider the weight of a storage system

full of water when initially considering your location-what supports or foundations, if any, will be necessary? If a storage system is located within a building, then its full mass must be integrated into any seismic and structural engineering studies. If a storage system is buried underground or located outside of the building, analyze soils in that location and construct foundations as needed.

Vegetated Roofs and Planters

Vegetated roofs “sponge” up a large percentage of the rain that falls on them. This percentage is based on vegetated roof depth and planting materials. In smaller rainfall events, some vegetated roofs will sponge up all rain that falls on them. When figuring rainwater harvest volumes, integrate this aspect of vegetated roofs into design calculations. Depending on the planting materials and roof construction, vegetated roofs may also discolor or contribute a high amount of particulates into your harvest system-this should be managed with appropriate system filters.

Design Approach

Design Team

From the earliest stage of design it is important to have all integrated team members on board with the design process. This will allow for identification of team member roles and responsibilities. This is important as some design responsibilities will be new to team members who have not previously participated in the design of water harvest systems. It is typical for team members participating in the design process to include the following roles in their design scope:

Architect leads and coordinates the design process and keeps everyone on task.

Civil Engineer calculates rain flow volumes and integrates any other water sources and uses into a water balance to

size the cistern volume. The civil engineer also connects to rainwater and greywater mechanical systems outside of the building footprint, and provides overflow to storm systems and ensures that overflow meets any local design criteria for storm water quality and/or quantity. The civil engineer will also design potable water connections outside of the building envelope.

Landscape Designer consults on water harvest projects where harvested water is to be used for irrigation-providing irrigation volumes for water balance calculations and specifying appropriate irrigation systems that work with the water harvest system.

Mechanical Engineer provides greywater and in-building reuse volumes to be used

Design Process

The harvest system design process is iterative. At each stage of the construction document design process, harvest system design assumptions should be verified by all contributing team members. It is common for design assumptions to change-contributing roof areas, irrigation demands and fixture counts, for instance-and it is important that the harvest system design reflect this.

for water balance calculations; designs roof drain systems and interior potable water delivery and sewage piping systems; identifies filter and water quality systems to meet reuse requirements; designs pump and delivery systems for water reuse. Pump and delivery systems may be located outside of the building envelope.

Electrical Engineer provides power to system elements as needed.

Geotechnical Engineer provides soil information used to determine if storage system foundations or supports are

needed.

Structural Engineer integrates full storage system loads into seismic calculations and building structural design, and/or determines need for foundations or supports outside of building.

Sustainability Consultant (optional) consults where rainwater harvesting is being used to pursue LEED credits or other accreditation systems, collaborating with the design team to ensure credit criteria are being met. Facilitates design charrettes to identify synergies with other sustainable design systems.

Design Synergies

Early design integration may also allow for economies in construction costs as the system can be integrated with other building systems and layout. Efforts to reduce water consumption throughout the project support a cost effective holistic water harvest design solution. User behavior patterns should reflect a high value placed on water with minimal

use of water and turning off faucets. When considering site irrigation, the use of drought tolerant and native species will reduce the amount of water needed-drip irrigation systems instead of spray systems will minimize water lost through evaporation. Also, consider using toilet fixtures with minimal or no water needed for sewage conveyance.

Storage System Sizing

The first step in a water harvest design process is to determine both the owner's annual water reuse goals and the volume of water available for annual harvest (Equation 1). Reuse goals may be directly related to obtaining credits as part of the LEED accreditation process. A potable water supply should be designed into all systems even if harvest volume is estimated to be greater than reuse volumes. A harvest system does not need to provide 100% of water used for a certain purpose-such as toilet flushing and irrigation-as long as it meets the owner's goals. A potable water supply will supply any water needs not met with the water harvested and will also supply water for maintenance when the storage system is emptied. Use Equation 2 below to determine rainwater harvest volumes. If greywater is being considered as

part of the harvest water make sure that the values used are based on realistic estimated user volumes instead of values used per code in the sizing of plumbing systems. Use of code values may result in unrealistically high values.

Equation 1: Total Annual Harvest Volume

Total Annual Harvest Volume = Total Annual Rainwater Harvest Volume + Total Annual Greywater Volume + Other Harvest Source Volumes

Total Annual Rainwater Harvest Volume:
See Equation 2

Total Annual Greywater Volume: Discuss with the project mechanical engineer, this number will be zero for Rainwater Harvest Systems.

Other Harvest Sources: This category may include harvested drill water, bleed/

blowdown water from cooling towers, etc.

Equation 2: Total Annual Rainwater Harvest Volume

Total Annual Rainwater Volume (CF) =
Rainwater Harvest Area(SF) * Collection
Efficiency* Local Annual Rainfall (FT)

Rainfall Harvest Area: The projected surface area of the portion of the roof that will be directed to the collection system.

Collection Efficiency: The percentage of the rainwater falling on the Harvest area that is assumed to enter the collection system. Assume 90% for a conventional metal rooftop. Assume 85% for composite or asphalt shingles. Consult with your civil engineer for alternative values to use for green roofs and other alternative roofing materials.

Local Annual Rainfall: Annual rainfall for the City of Seattle is typically estimated

at approximately 36 inches or 3 feet. (For more detailed information: http://www.seattle.gov/html/weather_averages.htm)

If the system is not shown to meet owner goals, revisit those goals and try additional scenarios. Once it has been ascertained that a system will meet the owner's objectives, the next step is to begin sizing the water storage system. This is often done with a monthly water balance system. Your team's civil engineer or sustainability consultant can help create a water balance spreadsheet specific to the needs of your project. A monthly water balance system can be used to show that the intent of LEED credits pursued is being met. More in-depth water harvest calculation methods are available but these methods, too, are only as reliable as the data input-often a best guess due to the fluctuation of rainfall conditions. A reserve volume may be added to the calculated volume to account for the uncertainty of many conditions.

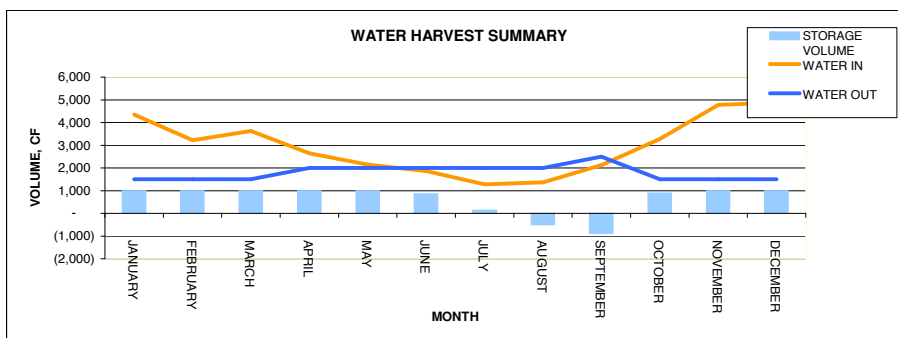
WATER HARVESTING AND REUSE CALCULATIONS:

PROJECT: RAINWATER HARVEST EXAMPLE
DATE: 1/1/2007

DESIGN CISTERN STORAGE VOLUME:
1,000 CF
7,481 GALL.

RAIN COLLECTION AREA:
COLLECTION AREA 11,590 SF
CATCHMENT FACTOR 0.90
EFFECTIVE COLLECTION AREA 10,431 SF

BEGINNING OF YEAR WATER REUSE VOLUME 1,000 CF



	WATER IN					WATER OUT				WATER BALANCE	
MONTH	MEDIAN RAINFALL, CITY OF SEATTLE INCHES	DAYS/ MTH	RAIN POTENTIAL CF	OTHER WATER SUPPLY TO TANK CF	TOTAL WATER IN CF	MONTHLY IRRIGATION DEMAND CF	OTHER DEMAND #1 CF	OTHER DEMAND #2 CF	TOTAL WATER OUT CF	END OF MONTH STORAGE VOLUME CF	MONTHLY STORAGE OVERFLOW CF
JANUARY	5.0	31	4,346	-	4,346	-	1,500	-	1,500	1,000	2,846
FEBRUARY	3.7	28	3,216	-	3,216	-	1,500	-	1,500	1,000	1,716
MARCH	3.3	31	2,869	755	3,623	-	1,500	-	1,500	1,000	2,123
APRIL	2.2	30	1,912	731	2,643	500	1,500	-	2,000	1,000	643
MAY	1.6	31	1,391	755	2,146	500	1,500	-	2,000	1,000	146
JUNE	1.3	30	1,130	731	1,861	500	1,500	-	2,000	861	-
JULY	0.6	31	522	755	1,276	500	1,500	-	2,000	137	-
AUGUST	0.7	31	608	755	1,363	500	1,500	-	2,000	(500)	-
SEPTEMBER	1.6	30	1,391	731	2,121	1,000	1,500	-	2,500	(878)	-
OCTOBER	2.9	31	2,521	755	3,276	-	1,500	-	1,500	897	-
NOVEMBER	5.5	30	4,781	-	4,781	-	1,500	-	1,500	1,000	3,178
DECEMBER	5.6	31	4,868	-	4,868	-	1,500	-	1,500	1,000	3,368
TOTALS	34.0		29,555	5,966	35,520	3,500	18,000	-	21,500		14,020

NOTES:
KEEP TRACK OF ALL OF YOUR DATA SOURCES IN A NOTES SECTION TO COMPARE WITH FUTURE DESIGN REVISIONS

MAYFLY ENGINEERING AND DESIGN, pllc

Rainwater Harvesting Water balance figure courtesy of Mayfly Engineering and Design, pllc, January 2007.

Design Challenges

Current water and sewer rates are low and life cycle costs must be analyzed to validate first costs.

Maintenance is increased compared to traditional potable water systems—the design team should specify system specific maintenance needs in the Operations and Maintenance Manual.

Increased coordination and design systems to address during design process.

Increase site space needed to site system components compared to traditional city water supply systems.

The figure (page 7) is an example of a simple water balance spreadsheet. The areas highlighted in blue are designed for user input and you progress through the iterative design process while the remaining cells and the graph are programmed to automatically update. Note the following trends shown on the water balance figure:

- During summer months when rainfall volume is low and irrigation needs high the cistern volume decreases. Potable water can be used to provide make-up water during these months.
- During months with high rainfall volumes a significant amount of water is overflowing the cistern.

- The total water in is greater than the total water out. If the cistern volume was increased to capture additional runoff then potable makeup water would not be needed in the summer months.

Once you have a feel for the size and potable water make-up needs of your system and a location is chosen it is crucial to communicate and collaborate with your design team on the details of the system. Make sure that the entire system from harvest source to reuse is included in plans and specifications in all phases of the design process.

Water Harvest Case Study: Fire Station 10



Rendering: Mike Kowalsk

Fire Station 10

The Fire Station 10 facility, located at 105 Fifth Avenue South in Seattle, Washington, houses three critical facilities for the Seattle's emergency and disaster response: Fire Station 10 Operations, the Emergency Operations Center, and the

Fire Alarm Center. The operations of the facility require that the building is designed and constructed for longevity, secure operations, high use service, and ease of maintenance.

Green Building Goals

A project goal for the design team was to incorporate sustainable design principles

and achieve LEED Certification of the facility. Sustainable design strategies

included: integrating site design elements with water efficiency measures, and reduction in process water use for apparatus wash and drills. In addition, approximately three-quarters of the facility will be covered with a vegetated roof, or green roof. LEED credits being pursued that rainwater harvesting contributes to include:

- Sustainable Sites Credit 6.1 Stormwater Design: Quantity Control

- Water Efficiency Credit 1.1 Water Efficient Landscaping: Reduce by 50%
- Water Efficiency Credit 1.2 Water Efficient Landscaping: No Potable Water Use or No irrigation
- Innovation in Design: Potable reduction for Process Water
- Innovation in Design: Education Credit

Water Harvest System

The Fire Station 10 design employs a water harvest system that will reuse the majority of the fire drill water used as well as the rainwater that falls on non-driving surfaces on the site. The design team estimates that nearly 130,000 gallons of water is projected to be used by a combination of the site landscaping and washing fire facility vehicles on an annual basis. The water captured in the cistern system will undergo a modest level of treatment and will be the sole source of water for plant irrigation. Water from the harvest system will also be available through a hose bib connection for fire personnel to use for vehicle washing purposes. The system was sized in order to meet 100 percent of the demand for both irrigation and vehicle washing. Water reuse for vehicle washing contributes to a LEED Innovation and Design Credit for Process Water Savings.

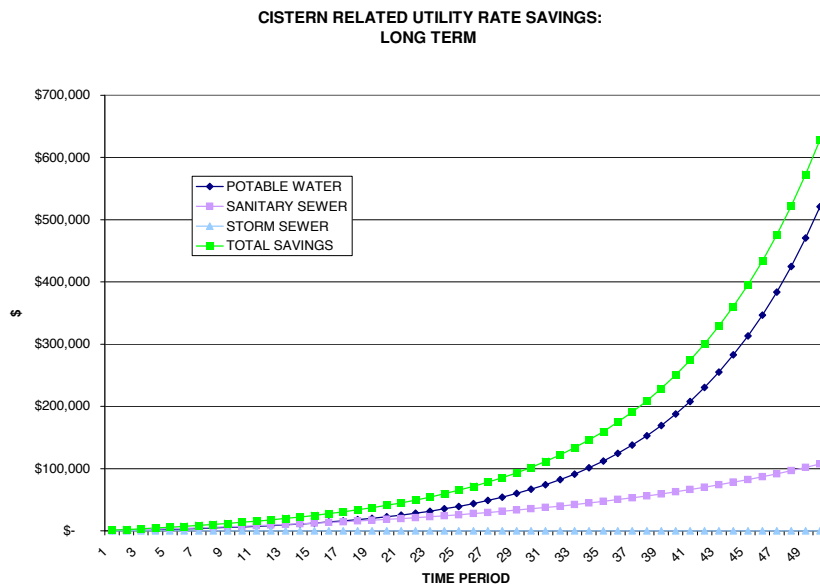
Design System Components:

- **Harvest sources:** Rainwater is collected from the portions of the roof that are not green roofs. Both rainwater and drillwater are captured from non-driving surfaces.
- **Collection systems:** A rain leader system within the building collects roof drainage from contributing areas. A trench drain system collects drill water runoff outside of the building. Both of these systems are conveyed to the storage system with conventional storm drainage conveyance.
- **Initial Water Quality Treatment:** A StormFilter system located in a 48" manhole provides initial water quality treatment.
- **Storage system:** A buried 1500 cubic foot corrugated metal pipe cistern provides storage volume. An overflow from the cistern is connected to the site's detention system in order to meet stormwater flow control requirements.
- **Delivery System:** A pump, located in a vault outside of the building, pressurizes the delivery system. A potable water feed is connected to the pump vault to provide make-up water when the cistern is empty.
- **Final Water Quality Treatment:** The planned uses for the reclaimed water did not require secondary treatment.
- **Operation and Maintenance Manual:** The design team will provide information regarding design intent and operations to be included in the facility operation and maintenance manual.
- **Education Program:** Information on the water harvest system will be included in the education program developed to meet the LEED Innovation in Design Credit for Education. The city's facility maintenance department is working on a measurement and verification program to incorporate the water use projections made during design and react if resource consumption is outside of the baseline conditions.

Cost

First costs for the Fire Station 10 rainwater harvesting system were estimated by Hoffman Construction in 2006 to total \$111,000. This included the following:

- Trench drain (to collect drill water): \$24,000
- Pump well: \$7,000
- Underground cistern: \$48,000
- Ozonation for cistern: \$5,000
- Misc. piping and controls: \$12,000
- Markups and tax: \$15,000



Water savings is shown to help pay back these first costs over the life of the project. The greatest volume of potable water saved is due to the water collected as runoff from drill operations. This water along with roof runoff is used to supply irrigation and truck washing water. While the fire department is not expected to pay Seattle Public Utilities (SPU) for drill water use, the cost of this water is still incurred by SPU and was included in the payback analysis.

Fire Station 10 SPU Utility Rate Savings courtesy of Mayfly Engineering and Design, April 2007.

While the first year of potable water cost savings is estimated to be just over \$1,000, if you apply the trend of sanitary and potable water rate increases seen over the last 10 years and an average inflation rate of 2%, you end up with a water savings of over \$111,000 in 31 years-paying back the first costs well before the building's useful life is over. Maintenance and Operation costs are not included in the above analysis; however, extending the lifecycle payback to 39 years would increase water saving to over \$228,000, providing more than \$117,000 to cover any additional Maintenance and Operations costs over the system lifecycle payback period.

Water harvest system design team members:

Architect: Weinstein AU Architects & Urban Designers

Civil & Structural Consultant: Magnusson Klemencic Associates

Mechanical Consultant: Notkin Engineers

Electrical & Technology Consultant: Sparling

Landscape Architect: Gustafson Guthrie Nichol Ltd.

Sustainability Consultant: Paladino & Company

To Learn More

Local public buildings that have integrated water harvesting systems include:

- Fire Station 10, Seattle, Washington

- King Street Center, Seattle, Washington
- Seattle Central Library, Seattle, Washington

- Seattle City Hall, Seattle, WA
- Washington Middle School, Olympia, Washington
- Cascade Eco-Renovation, Seattle, Washington

- Carkeek Park Environmental Center, Seattle, Washington

For more information about the Fire Station 10 project, contact the City of Seattle Fleets and Facilities Department at www.seattle.gov/fleetsfacilities/firelevy.

Regulations, Guidelines and Design Resources

Depending on whether you are considering a rainwater or greywater harvest system the following publications may be of use:

- The 2003 Uniform Plumbing Code (UPC), as enforced by the King County Public Health Department provides guidance on rainwater and greywater harvesting. UPC Chapter 6 - Water Supply and Distribution covers Potable, Non-potable, and Reclaimed Water use, including "backflow prevention". UPC Appendix J covers reclaimed water for non-residential buildings.
- The Washington State Building Code Council developed guidelines for non-residential rainwater harvesting in 2002. Call the Council at (360) 725-2964 to obtain a copy of these guidelines.
- The Washington State Department of Ecology provides "Ecology Criteria for Sewage Works Design" also known as the Orange Book. Chapter E1 on Reclaimed Water includes discussion on various classes of reclaimed water and their possible reuses. This document can be found at <http://www.ecy.wa.gov/pubs/9837/e1.pdf>.
- The Washington State Department of Health published, "Water Conserving On-Site Wastewater Treatment Systems-Recommended Standards and Guidance for Performance, Application, Design, and Operation & Maintenance," with an effective date of January 2007. This publication is divided into sections on Waterless Toilets, Greywater Systems and Subsurface Drip Dispersal Systems for greywater use in irrigation. This

publication can be found at <http://www.doh.wa.gov/ehp/ts/ww/rsg-water- conserve-sys-jan-2007.doc>.

- National Sanitation Foundation International (NSF) is an independent testing and certification organization that provides information on the performance of various filters. Visit their website at <http://www.nsf.org/> to obtain product information on specific water quality system components.
- The American Rainwater Catchment Systems Association (ARCSA) provides guidance on water harvesting. Available on their website is "The Texas Manual on Rainwater Harvesting." This document as well as other design documents can be found at <http://www.arcsa-usa.org/publications.aspx>.
- "Implement: Seattle's Sustainable Building Tool" provides a basic tool to evaluate water harvesting strategies. Visit their website at <http://www2.ci.seattle.wa.us/Implement/>.

Seattle Public Utilities (SPU) is currently working with the Department of Ecology to secure water rights for rainwater harvesting in Seattle combined sewer neighborhoods. Visit the SPU website at http://www.seattle.gov/util/About_SPU/Water_System/Projects/RainwaterPermit/ for a map of combined sewer neighborhoods and additional information regarding the water rights program. Contact Paul Fleming at paul.fleming@seattle.gov or at (206) 684-7626 for information regarding project permit requirements related to water rights.

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